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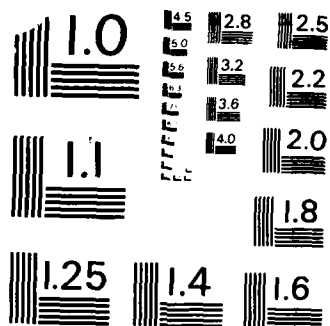
DETERIORATION OF FUEL STORED IN THE TROPICS (U) ARMY
TROPIC TEST CENTER APO NIAHI 34004 F CHEN OCT 84

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TECOM PROJECT NO. 7-CO-IL4-TT1-001
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FINAL REPORT
OF
DETERIORATION OF FUEL
STORED IN THE TROPICS

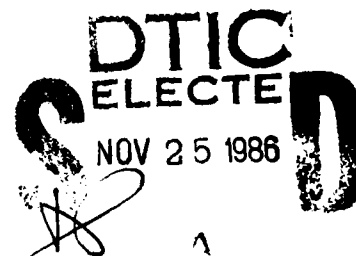
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UNITED STATES ARMY TROPIC TEST CENTER

APO MIAMI 34004

OCTOBER 1984



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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Gasoline, Automotive (Mogas); Turbine Fuel, Aviation (JP-4) and Fuel Oil, Diesel (DF-2) were exposed for two years in 55-gallon steel drums at the USATTC Fort Clayton POL Tank Farm. The number of Mogas samples found failing the distillation, unwashed gum content and color tests increased with increased exposure. Results were basically similar for samples exposed in both shaded and unshaded exposure modes. JP-4 samples exhibited low Reid Vapor Pressure at the end of the test. DF-2 samples did not exhibit any deterioration throughout the test.		

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FOREWORD

The assistance of Mr. S. Campbell, Laboratory-Technician, U.S. Navy Petroleum, Oil and Lubricant (POL) Laboratory, Fort Amador, Panama, in performing most of the property tests, is acknowledged.

1. BACKGROUND

1.1 The U.S. Army Tropic Test Center uses petroleum distillate fuels to test portable fuel tanks, collapsible fuel tanks and other POL handling devices (reference 1). A question that frequently arises during materiel testing is whether the petroleum distillate fuels deteriorate when they are being used for materiel testing and when they are in storage. Fuel deterioration and its contamination by deterioration products may result in serious failure of materiel end-items. Two important questions in the testing of collapsible POL tanks are whether the fuel deteriorates the tank material or whether the fuel picks up some contaminants from the tank fabric which could render it unserviceable. In order to determine if there is no interaction between the tank and the fuel, we must know the "normal" changes which occur in fuel during storage in the humid tropics.

2. OBJECTIVES

2.1 The main objective of this study was to determine if gasoline, automotive (Mogas); turbine fuel, aviation (JP-4) and fuel oil, diesel, regular grade (DF-2) deteriorate when stored in the humid tropics. These types of fuel are used extensively by the U.S. Army.

2.2 This investigation seeks to develop methods for the early recognition and measurement of environmentally related deterioration of fuels in storage. Results of this study may be used in revisions and additions to US Army Test and Evaluation Command Test Operations Procedures (TOP) which provide guidance to test officers for the evaluation of field storage, the early detection of fuel deterioration and to monitor the compatibility between fuel and materiel test items. Examples of applicable TOPs are listed in references 2 thru 4.

3. PROCEDURES

3.1 Exposure Testing

3.1.1 Two 55-gallon steel drums each, of Mogas, JP4 and DF-2 were exposed for two years at the Fort Clayton POL Tank Farm (FCPOL). One drum of each type of fuel was exposed on a rack, near the weather measuring equipment shed at the entrance of FCPOL. This exposure site is uncovered and unshaded from neighboring trees and buildings most of the day. The other three drums were exposed inside a covered open-sided storage facility at FCPOL. A gallon of fuel from each drum was sampled monthly and tested for its physical and chemical properties.

3.1.2 The fuel samples were procured from locally available sources with manufacture date unknown.

3.2 Property Testing

3.2.1 Physical and chemical properties tests were made to determine if the fuels met the requirements specified by their respective standards (references 5 thru 7) after their exposure. The tests that were run for each

fuel are listed in Tables B1 thru B3, Appendix B. (Not all the property tests listed in the standards were performed. The tests listed in Tables B1 thru B3, appendix B, were selected on the basis of the equipment available at the U.S. Navy POL Laboratory, Fort Amador, Panama, when this study was made). The required values associated with each American Society for Testing and Materials (ASTM) or Federal Standard Test Method (FSTM) are also listed in Tables B1 thru B3, Appendix B, (references 5 thru 28). The importance of each property test and the relationship between the property and the intended use of the fuels are described in detail in the Department of the Army Technical Manual TM-10-1165 (reference 29).

3.2.2 The property tests were performed at the US Navy POL Laboratory, Fort Amador, Panama. This laboratory has since moved to Rodman Naval Station, Panama.

4. RESULTS

The property test results for Mogas exposed in the uncovered mode are presented in Table C-1, Appendix C. The results for Mogas exposed in the covered mode are presented in Table C-2, Appendix C. Tables C-3 and C-4, Appendix C, present the results for JP-4 samples exposed in the uncovered and covered modes respectively. The results for DF-2 exposed in the uncovered mode are presented in Table C-5, Appendix C; and the results for DF-2 exposed in the covered mode are presented in Table C-6, Appendix C.

5. DISCUSSION

5.1 The Mogas fuel samples exposed in both the uncovered and covered modes were found to fail extensively when their property test results were compared with their respective requirement values. The comparative test results for uncovered and covered exposure modes are presented in Tables C-7 and C-8, Appendix C, respectively.

5.1.1 The Mogas samples were found to exhibit low Reid Vapor Pressure values and high lead contents from the start of the test. These property values changed with increased exposure. The Reid Vapor Pressure decreased while the lead content increased. The observed value changes indicate that deterioration continued with exposure although the initial failures cannot be attributed to environmental exposure.

5.1.2 The instances of Mogas samples failing the distillation, gum, and color tests were found to increase with increased exposure in both exposure modes.

5.1.2.1 The temperature to recover the distillation fractions was found to increase with increased exposure. This is an indication of increased loss of the lighter and more volatile fractions.

5.1.2.2 The gum content was also found to be increasing with increased exposure and exceeded the requirement value after a year of exposure. The

gum level was found to be much higher in the sample exposed in the uncovered mode than in the covered mode. Gum in gasoline is generally the resinous material that remains following volatilization of the fuel. It is related to the degradation of some components of Mogas manufactured by the cracking process and to those samples stored in harsh environments for a long period of time (reference 29). The higher levels of gum found in samples exposed in the uncovered mode than in the covered mode can be attributed to the higher ambient temperatures of the uncovered surfaces. The deleterious effects of gum are that it may clog fuel lines, cause sticky intake valves and coat the intake manifolds. Lepera (reference 30) reported five incidents of fuel oriented problems at Aberdeen Proving Ground during 1967. These incidents were due to stuck injectors and plugged fuel filters. They were attributed to high levels of gum in the fuel.

5.1.2.3 The failure of the color test is related to deterioration of the dyes used to color the fuel or to the presence of contaminants. The color test is used mainly as indication of uniformity of quality of the fuel (reference 29).

5.1.3 The failures for the water and sediment tests were too scattered to be considered as due to environmental effects. No attempts were made to check the bottom of the drums for water or sediments.

5.2 The JP-4 samples exposed in both the uncovered and covered modes exhibited occasional failures when their property test results were compared with the requirement values except for the color test where all samples failed. The comparative test results for uncovered and covered modes are presented in Tables C-9 and C-10, Appendix C, respectively.

5.2.1 All the JP-4 samples were found to have a darker color than required at the initiation of the test. No color change was found with increased exposure. As such, this test failure cannot be attributed to environmental effects.

5.2.2 Some of the distillation test results were outside the required ranges. The failures were too scattered for them to be considered as due to environmental effects. However, it was found that the temperature to recover the lighter fractions increased continuously at the latter stages of the test. This is an indication that the lighter and more volatile fractions were lost.

5.2.3 The JP-4 samples exposed at both exposure modes started to fail the Reid Vapor Pressure test at the end of the exposure test. Their pressure values were lower than that required. This is also an indication that the lighter and more volatile fractions were lost.

5.3 The DF-2 samples did not fail any of their requirement tests. This is because it is a less volatile fuel than Mogas or JP-4 and with heavier molecular weight components.

6. CONCLUSIONS

6.1 The major cause of fuel deterioration while stored in the humid tropics is volatilization and loss of lighter components.

6.2 Mogas was found to be the most affected fuel because it is the most volatile mixture tested.

6.3 JP-4, which is less volatile, showed signs of deterioration but remained basically within specified requirements.

6.4 DF-2, least volatile of the fuels tested, showed no signs of deterioration.

7. RECOMMENDATIONS

7.1 Data obtained from fuel testing should be used as base line for measuring effects of fuels on collapsible fuel tanks and vice versa.

7.2 Mogas and JP-4 should be tested before use in test items.

7.3 The Reid Vapor Pressure and Distillation Curve are properties that will provide early indications of fuel deterioration, especially for Mogas and JP-4. In addition, Mogas should also be checked for its gum content.

7.4 TOP 9-2-294 (reference 4) should recommend testing with gummy contaminants when applicable. Current recommendations are to test with water and solid contaminants only.

16. American Society for Testing and Materials, "Test for Kinematic Viscosity of Transparent and Opaque Liquids (and the Calculation of Dynamic Viscosity)", D-445, Philadelphia, PA.
17. American Society for Testing and Materials, "Test for Ash from Petroleum Products", D-482, Philadelphia, PA.
18. American Society for Testing and Materials, "Test for Ramsbottom Carbon Residue of Petroleum Products", D-524, Philadelphia, PA.
19. American Society for Testing and Materials, "Test for Oxidation Stability of Gasoline (Induction Period Method)", D-525, Philadelphia, PA.
20. American Society for Testing and Materials, "Test for Neutralization Number by Color-Indicator Titration", D-974, Philadelphia, PA.
21. American Society for Testing and Materials, "Calculated Cetane Index of Distillate Fuels", D-976, Philadelphia, PA.
22. American Society for Testing and Materials, "Test for Water Reaction of Aviation Fuels", D-1094, Philadelphia, PA.
23. American Society for Testing and Materials, "Test for Density, Specific Gravity, or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method", D-1298, Philadelphia, PA.
24. American Society for Testing and Materials, "Estimation of Net Heat of Combustion of Aviation Fuels", D-1405, Philadelphia, PA.
25. American Society for Testing and Materials, "Tests for Particulate Contaminant in Aviation Turbine Fuels", D-2276, Philadelphia, PA.
26. American Society for Testing and Materials, "Test for Lead in Gasoline, Volumetric Chromate Method", D-2547, Philadelphia, PA.
27. American Society for Testing and Materials, "Test for Water and Sediment in Distillate Fuels by Centrifuge", D-2709, Philadelphia, PA.
28. Federal Standard Test Method (FSTM) 5340, "Inhibitor, Fuel System Icing in Hydrocarbon Fuels (Refractometer Method)", Federal Test Method Standard 791B, "Lubricants, Liquid Fuels and Related Products, Methods of Testing". March 8, 1972.
29. Department of the Army Technical Manual, TM 10-1165 "Significance of ASTM Tests for Petroleum Products". Headquarters, Department of the Army, Washington D.C. March 1969.
30. Lepera, Maurice E., "Thermal-Oxidative Stability of Automotive Diesel Fuels", U.S. Army Mobility Equipment Research and Development Center, Coating and Chemical Laboratory, Aberdeen Proving Ground, MD; CCL Report No. 321, February 1973.

APPENDIX A. REFERENCES

1. U.S. Army Tropic Test Center, Materiel Testing in the Tropics, TECOM Project No. 9-CO-150-000-099, Fort Clayton, Canal Zone, April 1979.
2. TOP 2-2-701 U.S. Army Test and Evaluation Command Test Operations Procedure "Fuels and Lubricants", 2 July 1976.
3. TOP 9-2-235 U.S. Army Test and Evaluation Command Commodity Service Test Procedure "Tanks, Petroleum Liquid Storage, Fabric, Collapsible", 9 June 1967.
4. TOP 9-2-294 U.S. Army Test and Evaluation Command System Engineering Test Operations Procedure "POL Support Equipment", 14 Jan 1972.
5. Military Specification, "Gasoline, Automotive, Combat", MIL-G-3056D, 5 July 1979.
6. Military Specification, "Turbine Fuel, Aviation, Grades JP-4 and JP-5", MIL-T-5624L, 18 May 1979.
7. Federal Specification, "Fuel Oil, Diesel", VV-F-800C, 15 September 1980.
8. Federal Test Method Standard No. 791B, "Lubricants, Liquid Fuels and Related Products, Methods of Testing", 15 Jan 1969.
9. American Society for Testing and Materials, "Test for Distillation of Petroleum Products", D-86, Philadelphia, PA.
10. American Society for Testing and Materials, "Test for Flash Point by Pensky-Martens Closed Tester", D-93, Philadelphia, PA.
11. American Society for Testing and Materials, "Test for Detection of Copper Corrosion from Petroleum Products by the Copper Strip Tarnish Method", D-130, Philadelphia, PA.
12. American Society for Testing and Materials, "Test for Saybolt Color of Petroleum Products (Saybolt Chromometer Method)", D-156, Philadelphia PA.
13. American Society for Testing and Materials, "Test for API Gravity of Crude Petroleum and Petroleum Products (Hydrometer Method)", D-287, Philadelphia, PA.
14. American Society for Testing and Materials, "Test for Vapor Pressure of Petroleum Products (Reid Method)", D-323, Philadelphia, PA.
15. American Society for Testing and Materials, "Test for Existent Gum in Fuel by Jet Evaporation", D-381, Philadelphia, PA.

APPENDIX B. LIST OF PROPERTY REQUIREMENTS

TABLE B-1. PHYSICAL AND CHEMICAL REQUIREMENTS FOR MOGAS

<u>Property</u>	<u>Range or Value</u>	<u>Test Method ASTM Standard</u>
Distillation, °F		D-086
10% Recovered	122-158	
50% Recovered	192-239	
90% Recovered	270-356	
Residue, % vol, max	2.0	
Reid Vapor Pressure, psi @ 100 °F	7-9	D-323
Unwashed Gum, mg/100 ml, max	4	D-381
Corrosiveness @ 122 °F, max	1	D-130
Oxidation Stability, minutes, min	480	D-525
Color	Red, equal to standard	-----
Lead, g/gal, max	1.88	D-2547
Water and Sediment, % vol, max	0.01	D-2709

TABLE B-2. PHYSICAL AND CHEMICAL REQUIREMENTS FOR JP-4

Property	Range or Value	Test Method ASTM (or FSTM) Standard
Distillation, °F		D-86
Initial Boiling Point	Report	
10% Recovered	Report	
20% Recovered, max	293	
50% Recovered, max	374	
90% Recovered, max	473	
End Point, max	518	
Residue, % vol, max	1.5	
Loss, % vol, max	1.5	
API Gravity	45-57	D-1298
Existing Gum, mg/100 mg, max	7	D-381
Reid Vapor Pressure, psi @ 100 °F	2-3	D-323
Fuel Icing Inhibitor, % vol	0.10-0.15	FSTM-5340
Particulate Matter, mg/l	1.0	D-2276
Water Reaction, Interface rating, max	1b	D-1094
Color, Saybolt	1	D-156
Heating Value, (Aniline- gravity product) min	5,250	D-1405
Corrosion, Copper Strip, max	1b	D-130

TABLE B-3. PHYSICAL AND CHEMICAL REQUIREMENTS FOR DF-2 (OCONUS)

<u>Property</u>	<u>Range or Value</u>	<u>Test Method ASTM Standard</u>
Flash Point, min, °F	132.8	D-93
Kinematic Viscosity, @ 68 °F, cSt	1.8-9.5	D-445
Particulate Contamination, mg/l, max	10	D-2709
Carbon Residue, % weight, max	0.2	D-524
Ash, % weight, max	0.02	D-482
Corrosion, Copper Strip, max	#1	D-130
Cetane Number, min	45	D-976
Distillation, °F		D-86
50% Evaporation	Report	
90% Evaporation, max	674	
End Point, max	698	
Residue, vol %, max	3	
API Gravity	33.5-42.1	D-1298
Neutralization Number, TAN, max	0.10	D-974

APPENDIX C. TEST RESULTS

TABLE C-1. TEST RESULTS FOR MOGAS, EXPOSURE MODE: UNCOVERED

Tests	Julian Date										
	6173	6228	6246	6285	6312	6347	7010	7034	7066	7104	7126
Water and Sediment, % Vol.	Neg.	Neg.	Neg.	Neg.	0.02	Neg.	Neg.	Neg.	Neg.	0.01	Neg.
Color	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
Lead, g/gal	1.98	1.44	2.03	1.62	N.	2.18	1.59	1.51	1.66	1.65	2.24
Oxidation Stability, minutes	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
Distillation, °F											
10% Recovered	148	148	148	144	146	146	142	142	152	154	152
50% Recovered	230	232	232	236	242	242	236	232	270	274	270
90% Recovered	356	354	354	360	362	364	362	354	364	366	364
Residue, % Vol.	1.8	1.6	1.5	1.4	2.0	N.	0.8	0.6	0.5	0.6	0.5
Reid Vapor Pressure, psi	6.5	6.2	6.5	6.5	6.3	6.2	6.7	6.5	5.8	6.0	6.0
API Gravity	57.4	56.9	56.9	56.8	57.1	57.1	56.7	56.9	56.8	56.9	56.7
Unwashed Gum, mg/100 ml	3.5	2.4	4.0	2.5	3.6	3.6	2.6	3.0	3.6	3.4	2.9
Corrosiveness	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	#1	#1	Pass

N: Not Reported

Table C-1 (concluded)

Tests	Julian Date									
	7193	7237	7270	7305	7340	8006	8017	8062	8097	8124
Water and Sediment, % Vol.	Trace	Trace	Trace	Trace	Neg.	Trace	0.05	Trace	Neg.	Trace
Color	Red	Red	Red	Red	Lt.Red	Lt.Red	Lt.Red	Red	Red	Red
Lead, g/gal	1.53	1.6	1.54	1.67	2.04	2.06	2.05	2.10	2.13	2.42
Oxidation Stability, minutes	Fail	N.	N.	N.	N.	N.	N.	N.	N.	N.
Distillation, °F										
10% Recovered	146	148	152	158	162	168	174	182	190	198
50% Recovered	220	222	224	268	236	242	246	254	258	264
90% Recovered	342	342	342	364	350	352	352	356	358	358
Residue, % Vol.	0.4	0.6	0.6	0.6	0.8	0.6	0.4	0.6	0.8	0.6
Reid Vapor Pressure, psi	4.7	5.0	5.6	5.7	4.0	4.0	3.6	N.	2.7	2.5
API Gravity	60.0	N.	N.	N.	N.	55.7	54.9	53.3	N.	51.0
Unwashed Gum, mg/100ml	11.7	9.4	10.7	14.0	16.0	17.8	19.0	31.8	38.6	56.0
Corrosiveness	Pass	Pass	#1	Pass	#1	#1	#1	#1	#1	#1

N: Not Reported

TABLE C-2. TEST RESULTS FOR MOGAS, EXPOSURE MODE: COVERED

Tests	Julian Date										
	6173	6228	6246	6285	6312	6347	7010	7034	7066	7104	7126
Water and Sediment, % Vol.	Neg.	Neg.	Neg.	Neg.	0.02	Neg.	Neg.	Neg.	Neg.	0.01	Neg.
Color	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
Lead, g/gal	1.98	1.44	2.03	1.62	N.	2.18	1.59	1.51	1.66	1.65	2.24
Oxidation Stability, minutes	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
Distillation, °F											
10% Recovered	148	148	148	144	146	146	142	142	152	154	152
50% Recovered	232	232	232	236	242	242	236	232	264	274	270
90% Recovered	356	354	354	360	362	364	362	354	364	366	364
Residue, % Vol.	1.8	1.6	1.5	1.4	2.0	N.	0.8	0.6	0.5	0.6	0.5
Reid Vapor Pressure, psi	6.5	6.2	6.5	6.5	6.3	6.2	6.7	6.5	5.8	6.0	6.0
API Gravity	57.4	56.9	56.9	56.8	57.1	57.1	56.7	56.9	56.8	56.9	56.7
Unwashed Gum, mg/100 ml	3.5	2.4	4.0	2.5	3.6	3.6	2.6	3.0	3.6	3.4	2.9
Corrosiveness	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	#1	#1	Pass

N: Not Reported

Table C-2 (concluded)

Tests	Julian Date									
	7193	7237	7270	7305	7340	8006	8017	8062	8097	8124
Water and Sediment, Vol.	Trace	0.1	0.1	Trace	Neg.	Trace	0.05	0.1	Trace	Trace
Color	Red	Red	Red	Red	Lt.Red	Lt.Red	Lt.Red	Lt.Red	Lt.Red	Lt.Red
Lead, g/gal	1.53	1.6	1.55	1.67	1.43	1.53	1.48	1.54	1.90	1.50
Oxidation Stability, minutes	Fail	N.	N.	N.	N.	N.	N.	N.	N.	N.
Distillation, °F										
10% Recovered	156	152	154	158	158	158	162	160	162	162
50% Recovered	274	232	274	230	276	274	282	276	278	278
90% Recovered	364	350	364	346	366	364	378	364	366	366
Residue, % Vol.	0.6	0.8	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Reid Vapor Pressure, psi	6.3	6.5	4.8	4.8	4.7	5.0	4.5	N.	4.9	5.0
API Gravity	56.5	N.	N.	N.	N.	56.0	55.4	56.0	N.	56.0
Unwashed Gum, mg/100 ml	7.3	5.2	1.3	22.0	4.0	4.4	3.0	4.6	4.9	11.2
Corrosiveness	Pass	Pass	Pass	Pass	#1	#1	#1	#1	#1	#1

N: Not Reported

TABLE C-3. TEST RESULTS FOR JP-4, EXPOSURE MODE: UNCOVERED

Tests	Julian Date									
	6173	6228	6246	6285	6312	6338	7010	7034	7066	7104
Distillation, °F										
Initial Boiling Point	140	142	142	140	144	N.	142	144	152	144
10% Recovered	210	212	212	206	212	N.	210	212	218	214
20% Recovered	240	240	240	240	240	N.	240	242	246	242
50% Recovered	322	324	324	326	321	N.	320	324	322	326
90% Recovered	462	462	462	466	460	N.	456	458	466	462
End Point	505	506	504	516	506	N.	502	504	524	508
Residue, % Vol.	1.0	1.0	1.0	1.0	1.0	N.	1.0	1.0	1.0	1.0
Loss, % Vol.	1.0	1.0	1.0	2.0	1.0	N.	1.0	1.0	0.5	1.0
API Gravity	49.2	49.7	49.3	49.2	49.5	49.7	49.6	49.5	49.4	49.4
Existing Gum, mg/100ml	2.7	3.8	4.2	2.3	2.0	2.0	2.6	3.0	1.9	4.6
Reid Vapor Pressure, psi	2.6	2.8	2.8	2.8	2.5	2.6	2.5	2.6	2.6	2.5
Heating Value	6445	6511	6458	6445	6484	N.	6498	6484	6471	N.
Corrosion, Copper strip	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	#1	#1
Water Reaction	#2	1	1b	1b	1b	1b	1b	1b	1b	1b
Fuel System Icing Inhibitor, % Vol.	0.13	0.13	0.13	0.11	0.13	0.13	0.11	0.13	0.13	0.13
Color, Saybolt	Straw	Straw	Straw	Straw	Straw	Straw	Straw	Straw	Straw	Straw

N: Not Reported

Table C-3 (concluded)

Tests	Julian Date										
	7126	7193	7220	7252	7291	7314	7353	8009	8046	8079	8104
Distillation, °F Initial Boiling Point 10% Recovered 20% Recovered 50% Recovered 90% Recovered End Point Residue, % Vol. Loss, % Vol.	156	152	150	156	162	160	160	166	170	180	180
	220	222	214	224	224	226	230	230	234	236	240
	250	248	246	250	252	252	254	256	258	260	264
	328	328	324	328	330	330	326	330	332	336	338
	460	460	456	460	460	462	462	462	460	464	462
	522	504	504	502	506	504	504	505	504	508	504
	1.0	0.8	0.8	0.8	1.0	1.0	1.0	0.8	1.0	1.0	1.0
	1.0	0.7	0.7	1.2	1.0	1.0	1.0	1.2	1.0	1.0	1.0
	48.7	48.8	48.7	48.6	48.9	48.5	48.2	48.0	47.7	47.7	47.5
	3.6	12.4	3.3	2.8	5.7	3.3	6.4	2.0	4.0	4.4	5.8
Reid Vapor Pressure, psi	2.6	2.5	2.5	1.7	2.0	1.7	1.5	1.3	N.	N.	1.5
Heating Value	N.	N.	N.	N.	N.	N.	N.	7440	6334	6334	6393
Corrosion, Copper Strip	#1	#1	Pass	Pass	#1	#1	#1	#1	#1	#1	#1
Water Reaction	1b	1b	1b	1b	1b	1b	1b	1b	1b	1b	1b
Fuel System Icing Inhibitor, % Vol.	0.13	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.07	0.07
Color, Saybolt	Straw	Straw	Straw	Straw	Straw	Straw	Straw	Straw	Straw	Straw	Straw

N: Not Reported

TABLE C-4. TEST RESULTS FOR JP-4, EXPOSURE MODE: COVERED

Tests	Julian Date							
	6173	6228	6246	6285	6312	6338	7010	7034
Distillation, °F								
Initial Boiling Point	140	142	142	140	144	N.	142	144
10% Recovered	210	212	212	206	212	N.	210	212
20% Recovered	240	240	240	240	240	N.	240	242
50% Recovered	322	324	324	326	321	N.	320	324
90% Recovered	462	462	462	466	460	N.	456	458
End Point	505	506	504	516	506	N.	502	504
Residue, % Vol.	1.0	1.0	1.0	1.0	1.0	N.	1.0	1.0
Loss, % Vol.	1.0	1.0	1.0	2.0	1.0	N.	1.0	1.0
API Gravity	49.2	49.7	49.3	49.2	49.5	49.7	49.6	49.5
Existing Gum, mg/100ml	2.7	3.8	4.2	2.3	2.0	2.0	2.6	3.0
Reid Vapor Pressure, psi	2.6	2.8	2.8	2.8	2.5	2.6	2.5	2.6
Heating Value	6445	6511	6458	6445	6484	N.	6498	6484
Corrosion, Copper strip	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
Water Reaction	#2	1	1b	1b	1b	1b	1b	1b
Fuel System Icing Inhibitor, % Vol.	0.13	0.13	0.13	0.11	0.13	0.13	0.11	0.13
Color, Saybolt	Straw	Straw	Straw	Straw	Straw	Straw	Straw	Straw

N: Not Reported

Table C-4 (concluded)

Tests	Julian Date										
	7126	7193	7220	7252	7291	7314	7353	8009	8046	8079	8104
Distillation, °F											
Initial Boiling Point	150	150	152	146	144	148	148	150	154	160	154
10% Recovered	226	214	216	214	206	212	212	218	220	220	218
20% Recovered	248	242	246	244	236	242	242	250	246	248	246
50% Recovered	324	322	324	310	318	324	324	346	332	328	328
90% Recovered	442	456	456	462	456	462	460	500	462	462	462
End Point	502	504	506	511	502	512	504	582	504	506	504
Residue, % Vol.	1.0	0.8	0.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.8
Loss, % Vol.	1.0	0.7	0.7	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.2
API Gravity	49.4	49.4	49.1	49.1	49.9	49.4	49.2	47.7	49.2	49.2	49.1
Existing Gum, mg/100ml	3.6	4.8	3.1	2.4	6.1	3.1	6.0	3.4	4.0	3.8	6.2
Reid Vapor Pressure, psi	2.6	2.5	2.5	2.0	2.4	2.3	2.0	1.7	N.	N.	N.
Heating Value	N.	N.	N.	N.	N.	N.	N.	7537	6534	6534	6520
Corrosion, Copper strip	#1	#1	Pass	Pass	#1	#1	#1	#1	#1	#1	#1
Water Reaction	1b	1b	1b	1b	1b	1b	1b	1b	1b	1b	1b
Fuel System Icing Inhibitor, % Vol	0.13	0.13	0.13	0.13	0.11	0.13	0.13	0.11	0.13	0.11	0.11
Color, Saybolt	Straw	Straw	Straw	Straw	Straw	Straw	Straw	Straw	Straw	Straw	Straw

N: Not Reported

TABLE C-5. TEST RESULTS FOR DF-2, EXPOSURE MODE: UNCOVERED

Tests	Julian Date									
	6173	6228	6246	6293	6322	7010	7040	7087	7116	7144
API Gravity, @ 60 °F	38.8	39.0	39.0	38.9	39.0	39.0	39.0	39.0	39.9	38.9
Flash Point, °F	134	160	162	162	162	154	156	154	158	158
Viscosity, cSt, 68 °F	2.83	2.67	2.78	2.8	2.82	2.81	2.80	2.80	2.72	2.80
Distillation, °F										
50% Evaporation	530	510	514	512	512	512	512	518	514	530
90% Evaporation	638	612	612	612	610	614	616	612	612	608
End Point	685	660	660	658	656	660	662	658	658	648
Residue, Vol. %	0	1.4	0	0	1.0	1.0	1.0	2.0	1.0	1.0
Particulate Contamination, mg/L	Neg.	Neg.	Neg.	Neg.	Trace	Neg.	Neg.	Neg.	0.001	0.001
Ash, weight %	0.0015	0.002	0.002	0	0	0.001	0.001	0.002	0.001	0.001
Carbon Residue weight, %	0.03	0.03	0.03	0.02	0.03	0.03	0.02	0.03	0.03	0.02
Neutralization Number, TAN	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral
Cetane Number	60.5	57.5	58.5	57.5	58.0	58.0	58.0	59.0	60.0	60.5
Corrosion Copper Strip	Pass	Pass	Pass	Pass	Pass	Pass	Pass	#1	#1	Pass

N: Not Reported

Table C-5 (concluded)

Tests	Julian Date									
	<u>7207</u>	<u>7237</u>	<u>7270</u>	<u>7305</u>	<u>7334</u>	<u>8006</u>	<u>8017</u>	<u>8062</u>	<u>8097</u>	<u>8124</u>
API Gravity, @ 60 °F	38.9	38.9	38.8	40.4	39.0	38.9	39.0	39.0	39.0	39.0
Flash Point, °F	156	160	160	162	160	160	140	160	162	160
Viscosity, cSt, 68 °F	2.76	2.78	2.75	2.25	2.73	2.74	2.68	2.78	2.73	2.76
Distillation, °F										
50% Evaporation	516	518	516	512	514	516	516	514	514	514
90% Evaporation	614	618	612	618	616	618	616	614	614	614
End Point	652	654	660	662	664	664	664	662	660	662
Residue, Vol. %	1.8	2.0	2.0	2.0	2.6	3.0	2.0	2.0	2.0	2.2
Particulate Contamination, mg/L	Trace	Trace	Trace	Trace	0.002	Trace	Trace	Trace	Neg.	Trace
Ash, weight %	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.0
Carbon Residue weight %	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.03
Neutralization Number, TAN	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral
Cetane Number	58.0	58.0	58.0	60.0	58.0	58.0	58.5	58.0	58.0	58.0
Corrosion Copper Strip	Pass	Pass	#1	Pass	#1	#1	#1	#1	#1	#1

N: Not Reported

TABLE C-6. TEST RESULTS FOR DF-2, EXPOSURE MODE: COVERED

Tests	Julian Date									
	6173	6228	6246	6293	6322	7010	7040	7087	7116	7144
API Gravity, @ 60 °F	38.8	39.0	39.0	38.9	39.0	39.0	39.0	39.0	39.9	38.9
Flash Point, °F	134	160	162	162	162	154	156	154	158	158
Viscosity, cSt, 68 °F	2.83	2.67	2.78	2.8	2.82	2.81	2.80	2.80	2.72	2.80
Distillation, °F										
	530	510	514	512	512	512	512	518	514	530
	638	612	612	612	610	614	616	612	612	608
	685	660	660	658	656	660	662	658	658	648
End Point										
Residue, Vol. %	0	1.4	0	0	1.0	1.0	1.0	2.0	1.0	1.0
Particulate Contamination, mg/L	Neg.	Neg.	Neg.	Neg.	Trace	Neg.	Neg.	Neg.	0.001	0.001
Ash, weight %	0.0015	0.002	0.002	0	0	0.001	0.001	0.002	0.001	0.001
Carbon Residue weight, %	0.03	0.03	0.03	0.02	0.03	0.03	0.02	0.03	0.03	0.02
Neutralization Number, TAN	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral
Cetane Number	60.5	57.5	58.5	57.5	58.0	58.0	58.0	59.0	60.0	60.5
Corrosion	Pass	Pass	Pass	Pass	Pass	Pass	Pass	#1	#1	Pass
Copper Strip										

N: Not Reported

Table C-6 (concluded)

Tests	Julian Date									
	<u>7207</u>	<u>7237</u>	<u>7270</u>	<u>7305</u>	<u>7334</u>	<u>8006</u>	<u>8017</u>	<u>8062</u>	<u>8097</u>	<u>8124</u>
API Gravity, @ 60 °F	38.9	38.9	38.8	40.4	39.0	38.9	39.0	39.0	39.0	39.0
Flash Point, °F	156	160	160	162	160	160	140	160	162	160
Viscosity, cSt, 68 °F	2.76	2.78	2.75	2.25	2.73	2.74	2.68	2.78	2.73	2.76
Distillation, °F										
50% Evaporation	516	518	516	512	514	516	516	514	514	514
90% Evaporation	614	618	612	618	616	618	616	614	614	614
End Point	652	654	660	662	664	664	664	662	660	662
Residue, Vol. %	1.8	2.0	2.0	2.0	2.6	3.0	2.0	2.0	2.0	2.2
Particulate Contamination, mg/L	Trace	Trace	Trace	Trace	0.002	Trace	Trace	Trace	Neg.	Trace
Asst, weight %	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.0
Carbon Residue weight %	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.03
Neutralization Number, TAN	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral
Cetane Number	58.0	58.0	58.0	60.0	58.0	58.0	58.5	58.0	58.0	58.0
Corrosion Copper Strip	Pass	Pass	#1	Pass	#1	#1	#1	#1	#1	#1

N: Not Reported

TABLE C-7. COMPARISON BETWEEN TEST RESULTS AND REQUIREMENT VALUES
FOR MOGAS, EXPOSURE MODE: UNCOVERED

Requirement	Julian Date															
	6173	6228	6246	6385	6312	6347	7010	7034	7066	7104	7126	7193	7237	7270	7305	7340
Distillation, °F																
10% Recovered					F	F			F	F	F	F	F	F	F	F
50% Recovered				F	F	F	F		F	F	F	F	F	F	F	F
90% Recovered																
Residue					N											
Reid Vapor Pressure	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F
Unwashed Gum																
Corrosiveness @ 122 °F																
Oxidation Stability																
Color																
Lead	F	F	F	N	F											
Water and Sediment																

F: Failure
N: Not Reported

TABLE C-8. COMPARISON BETWEEN TEST RESULTS AND REQUIREMENT VALUES
FOR MOGAS, EXPOSURE MODE: COVERED

Requirement	Julian Date																				
	6173	6228	6246	6385	6312	6347	7010	7034	7066	7104	7126	7193	7237	7270	7305	7340	8006	8017	8062	8097	8124
Distillation, °F																					
10% Recovered					F	F			F	F	F	F	F	F		F	F	F	F	F	F
50% Recovered					F	F	F		F	F	F	F	F	F	F	F	F	F	F	F	F
90% Recovered				F	F	N															
Residue																					
Reid Vapor Pressure	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	N	F	F
Unwashed Gum												F		F							F
Corrosiveness @ 122 °F																					
Oxidation Stability												F	N	N	N	N	N	N	N	N	N
Color																F	F	F	F	F	F
Lead	F		F		N	F					F										F
Water and Sediment					F								F	F			F	F			
F: Failure																					
N: Not Reported																					

F: Failure
N: Not Reported

TABLE C-9. COMPARISON BETWEEN TEST RESULTS AND REQUIREMENT VALUES
FOR JP-4, EXPOSURE MODE: UNCOVERED

<u>Requirement</u>	<u>Julian Date</u>	<u>6173</u>	<u>6228</u>	<u>6246</u>	<u>6385</u>	<u>6312</u>	<u>6347</u>	<u>7010</u>	<u>7034</u>	<u>7066</u>	<u>7104</u>	<u>7126</u>	<u>7193</u>	<u>7237</u>	<u>7270</u>	<u>7305</u>	<u>7340</u>	<u>8006</u>	<u>8017</u>	<u>8062</u>	<u>8097</u>	<u>8124</u>
Distillation					N						F											
Initial Boiling Point																						
10% Recovered					N																	
20% Recovered					N																	
50% Recovered					N																	
90% Recovered					N																	
End Point					N																	
Residue					N																	
Loss				F	N																	
API Gravity																						
Existing Gumm																						
Reid Vapor Pressure														F		F	F	N	N			
Heating Value															N	N	N					
Corrosion Copper Strip																						
Water Reaction, Interface rating																						
Fuel Icing Inhibitor																					F	F
Color, Saybolt		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F

F: Failure
N: Not Reported

TABLE C-10. COMPARISON BETWEEN TEST RESULTS WITH REQUIREMENT
VALUES FOR JP-4, EXPOSURE MODE: COVERED

Requirement	Julian Date														
	6173	6228	6246	6385	6312	6347	7010	7034	7066	7104	7126	7193	7237	7270	7340
Distillation															
Initial Boiling Point					N										
10% Recovered					N										
20% Recovered					N										
50% Recovered					N										
90% Recovered					N										
End Point					N										
Residue					N										
Loss			F		N										
API Gravity															
Existing Gum															
Reid Vapor Pressure															
Heating Value															
Corrosion Copper Strip					N										
Water Reaction, Interface Rating															
Fuel Icing Inhibitor															
Color Saybolt	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F

F: Failure
N: Not Reported

APPENDIX D. DISTRIBUTION LIST

Deterioration of Fuel Stored in the Tropics
TECOM Project No. 7-CO-IL4-TT1-001

<u>Addressee</u>	<u>Final Report</u>
Commandant US Army Chemical School ATTN: ATZN-CM-CT Fort McClellan, AL 36205	1
Commander US Army Electronic Proving Ground ATTN: STEEP-CS Fort Huachuca, AZ 85613	1
Director US Army Research and Technology Laboratories Ames Research Center ATTN: DAVDL-D Moffett Field, CA 94035	1
Commander US Army Natick Research and Development Center ATTN: STRNC-Y Natick, MA 01760	1
Commander US Army Combat Systems Test Activity ATTN: STECS Aberdeen Proving Ground, MD 21005	1
Commander/Director US Army Chemical Research and Development Center ATTN: AMDAR-CL Aberdeen Proving Ground, MD 21010	1
Commander US Army Test and Evaluation Command ATTN: AMSTE-AD-M Aberdeen Proving Ground, MD 21005	1
Commander US Army White Sands Missile Range ATTN: STEWS-SC STEWS-TE-AE White Sands Missile Range, NM 84022	1

<u>Addressee</u>	<u>Final Report</u>
Commander US Army Dugway Proving Ground ATTN: STEDP-SD Dugway, UT 84022	1
Administrator Defense Technical Information Center ATTN: DDA Cameron Station Alexandria, VA 22314	1
Commander US Army Materiel Command ATTN: AMCDRA-ST 5001 Eisenhower Avenue Alexandria, VA 22333	1
Commander & Director US Army Engineer Topographic Laboratories ATTN: ETL-GS-LB Fort Belvoir, VA 22060	1
Director Night Vision and Electro-Optics Laboratories ATTN: DELNV-RM Fort Belvoir, VA 22060	1
Commander US Army Tropic Test Center ATTN: STETC-MTD	1
STETC-MTD-P	5
STETC-MTD-T	1
STETC-MTD-A	1
STETC-MTD-O (TIC)	10
STETC-MTD-O (Tech Ed)	2
STETC-LD	1
STETC-MD	1
STETC-ADP	1
STETC-CO	1
STETC-HHC	1
APC Miami 34004	

END

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